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Perceptual and conceptual similarities facilitate the generalization of instructed fear

Marc Bennett*, Ellen Vervoort, Yannick Boddez, Dirk Hermans & Frank Baeyens

Centre for Learning and Experimental Psychopathology, Faculty of Psychology and Educational Sciences, University of Leuven, Tiensestraat 102 - Box 3712, 3000 Leuven, Belgium, Tel: ++ 32 (0) 16 32 61 24; Email: marc.pat.bennett@gmail.com

*Corresponding Author

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Abstract

Background and objectives: Learned fear can generalize to neutral events due their perceptual and conceptual similarity with threat relevant stimuli. This study simultaneously examined these forms of generalization to model the expansion of fear in anxiety disorders.

Methods: First, artificial categories involving sounds, nonsense words and animal-like objects were established. Next, the words from one category were paired with threatening information while the words from the other category were paired with safety information. Lastly, we examined if fear generalized to (i) the conceptually related animal-like objects and (ii) other animal like-objects that were perceptually similar. This was measured using behavioural avoidance, US expectancy ratings and self-reported stimulus valence.

Results: Animal-like objects conceptually connected to the aversive words evoked heightened fear. Perceptual variants of these animal-like objects also elicit fear.

Limitations: Future research would benefit from the use of online-US expectancy ratings and physiological measures of fear.

Conclusions: Investigating the role of both perceptual and conceptual fear generalization is important to better understand the etiology of anxiety disorders symptoms.

Keywords: perceptual generalization, conceptual generalization, fear, anxiety disorders.

1. Introduction

A longstanding challenge in anxiety disorder research and therapy has been to explain the elaborate collection of events that evoke unwarranted fear (Coelho & Purkis, 2009; Rachman, 1977). It has been theorised that the *(over)-generalization* of fear is critically involved (see, Dymond, Dunsmoor, Roche, Vervliet, & Hermans, 2014; Lissek et al., 2005). This describes the spontaneous elicitation of fear to innocuous stimuli that did not feature in an aversive encounter but are similar to a stimulus that was present. The term 'similar' typically refers to either an apparent physical resemblance or an abstract conceptual sameness. However, little is known about how perceptual and conceptual information might be concurrently involved in fear generalization. This is surprising given that (threat relevant) stimuli can be connected both perceptually and conceptually to a whole series of other events (e.g. Fields, Reeve, Adams, & Verhave, 1991; Storms, 2003). For instance, if one was to fall victim of a traumatic car accident then other cars or roads could later evoke fear and avoidance, as might symbols of driving like traffic signs or keys (Dunsmoor & Murphy, in press). We argue that investigating the interconnections between perceptual and conceptual similarity is a necessary step in the development of a precise theoretical account of the expansion of fear in anxiety disorders.

Associative learning theorists often appeal to the composite features of a stimulus to explain perceptually based fear generalization (e.g. McLaren & Mackintosh, 2002; Pearce, 1987; Rescorla, 1976). It is assumed that each individual stimulus is composed of multiple elements and generalization between stimuli is the result of associative connections that originate from their common elements (Kalish, 1969). That is, a once neutral stimulus can excite the memory of an aversive outcome when it shares common elements with another stimulus that is already associated with that outcome. Following a frightening experience with an aggressive dog, for example, other animals sharing perceptual features with that dog may elicit fear. The perceptual generalization of fear is typically studied in laboratory studies by pairing a neutral, conditioned stimulus (CS+) with an unpleasant unconditioned stimulus (US), e.g. a brief electric shock. Next, and in the absence of the US, a number of stimuli that perceptually resemble the CS+ are presented. These physical variants are found to evoke heightened fear and, moreover, a gradient in the expression of fear can be observed across them. Variants that closely resemble the CS+ evoke more fear than variants that have less in common with the CS+ (e.g. Haddad, Xu, Raeder, & Lau, 2013; Lenaert, Boddez, Grifith, Vervliet, Schreurs, & Hermans, 2014; Lissek et al., 2010; Lommen, Englehart, & van den Hout, 2010).

Learned fear can also spread to neutral stimuli that are perceptually dissimilar from a threat relevant stimulus but are still alike in a conceptual sense (e.g. Dunsmoor, Martin, & LaBar, 2012). For instance, individuals with obsessive-compulsive disorder fear a diversity of triggers (e.g. dogs, gasoline and knifes) that are related in terms of their conceptual relevance (i.e. potentially life threatening; Hermans, Baeyens, & Vervliet, 2013; McGinn & Sanderson, 1999). In order to study conceptually based fear generalization, some researchers have taken to experimental studies wherein an artificial category is established with physically distinct stimuli like nonsense words- a *stimulus equivalence category*. This research makes use of an operant conditioning procedure known as a *matching-to-sample (MTS) task*. Here, a single item (*sample stimulus*) is first presented on the top of a computer screen for a few seconds and this is followed by a set of items on the bottom of the screen. Participants are instructed to select one item from the set based on the sample stimulus that had appeared. Several sets can be presented but, in each, there is one correct item (the *comparison stimulus*) and corrective feedback follows each choice. Therefore, a number of conditional relationships are initially trained such that different comparison stimuli are mutually related to same sample stimulus. In a later test phase, the emergence of coherent untrained relations is examined. Using the same format, albeit without corrective feedback, participants may select the sample stimulus when presented with a comparison stimulus (known as *symmetry relations*) and also select a comparison stimulus when presented with another of the comparison stimuli (known as *equivalence relations*). In essence, physically distinct stimuli become substitutable with one another and this is reasoned to resemble a conceptual sameness within a verbal category (Hayes, Barnes-Holmes, & Roche, 2001; Fields et al., 1991; Galizio, Stewart, & Pilgrim, 2001). In order to examine the generalization of fear through these artificial categories, one member (CS+) is repeatedly paired with an aversive US. Afterwards, other category members are typically found to elicit fear in the absence of the US (Dymond, Schlund, Roche, Whelan, Richards, & Davies, 2011; Valverde, Luciano, & Barnes-Holmes, 2009; Vervoort, Vervliet, Bennett, & Baeyens, 2014).

This research clearly indicates that fear generalization can be facilitated by either a physical or conceptual similarity between stimuli. But beyond the laboratory, the physical and conceptual features of events are not easily disentangled from one another and might simultaneously exacerbate generalization. By examining both forms of similarity together, we may better describe the ever-increasing array of events that can evoke fear. For that reason, the current study combined the above approaches and made use of both artificial stimulus equivalence categories and perceptual variants of category members. Specifically, we investigated whether a stimulus could evoke generalized fear because of its category membership and whether another stimulus could evoke generalized fear because of its perceptually similarity to category members.

Importantly, this study elected to use an instructed fear conditioning paradigm over a traditional Pavlovian fear conditioning. Rachman (1977) proposed that, next to direct experience with a US, hearing or reading about the threat value of a stimulus can also lead to fear and this is supported by extensive research (Dymond, Schlund, Roche, DeHouwer, & Freegard, 2012; Muris & Field, 2011; Ollendick & King, 1991; Ollson & Phelps, 2007; Raes, De Houwer, De Schryver, Brass & Kalisch, 2014). But despite the established importance of instructed fear conditioning in the acquisition of real-life fear, there are no studies (to the very best of our knowledge) that examine the potential for this this pathway to catalyze perceptual or conceptual generalization. We consider this to be an important topic for study.

In the current experiment, participants first selected a combination of unpleasant images and sounds although these would not appear during the experimental study (a sham-US). This was done to suggest that an aversive outcome was possible in the experimental context and motivate fear. Next, two stimulus equivalence categories were shaped using a MTS task. Nonsense words and animal-like objects acted as comparison stimuli that were mutualy related to common sample sounds. The nonsense word from one category was paired with threatening information and the nonsense word from the other category was paired with safety information. A final testing phase examined generalization to (i) other category members (animal-like objects) and (ii) perceptual variants of these members. Behavioral avoidance, retrospective US expectancy ratings and self-reported stimulus valence were recorded as our main dependent variables.

2. Method

2.1. Participants

Thirty undergraduate students (23 females) from the University of Leuven were recruited (M_{age} = 21 years, SD = 1.41 years) through an online experimental management system. None had previously taken part in research of this type and the sample size was based on previous research conducted in our lab. The faculty of psychology's ethical committee approved the study. All participants signed informed consent and were compensated with course credits (1 credit/hour) or money (€8/hour).

2.2. Apparatus

The experiment was programmed using Affect4 (Spruyt, Clarysse, Vansteenwegen, Baeyens, & Hermans, 2010) and ran on a Dell desktop PC with a 17" monitor with a white background inside a sound attenuated cubicle. Two 2 s sounds (A1 & A2) were the *sample stimuli*- a low-pitch constant tone (80db) and a high-pitch pulsing tone (90db). Three nonsense words (B1, B2 & B3) were shown in black Ariel font, size 32- “Veg”, “Lur” and “Mau”. Three sets of animal-like objects, with 2 objects in each set (150 x 150 pixels), were selected from an online catalogue (C1 & pC1; C2 & pC2; C3 & pC3; Barry, Griffith, De Rossi, & Hermans, 2014). Objects were perceptually similar within but not between sets (see Figure 1). Nonsense words and animal-like objects acted as *comparison stimuli*. These stimuli were members of two stimulus equivalence categories- *CAT+* (A1-B1-C1) and *CAT-* (A2-B2-C2). The assignment of tones, nonsense words and animal-like objects into these categories was counterbalanced across participants.

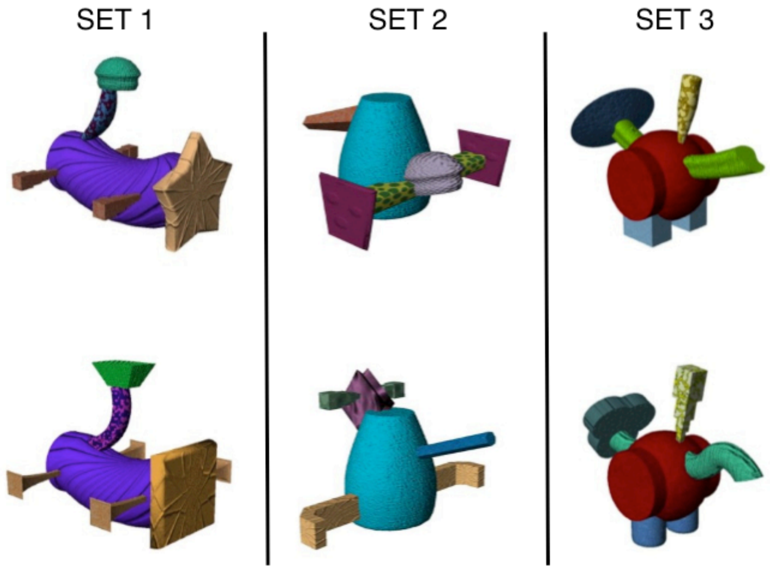

Figure 1. The non-sense animal-like objects, which were used as ‘C’ stimuli. There are 3 sets and the objects are similar within these but not between.

The sham-US was a compound of an unpleasant image and noise. Three images (1024x768 pixels) were selected from the International Affective Picture System (IAPS; Lang, Bradley & Cuthbert, 2001) based on the arousal ratings of young adults (Grühn & Scheibe, 2008). Images were presented for 3 s and included a mutilated hand ($M_{arousal}$ = 7.4; high aversion), a tribal mutilation ($M_{arousal}$ = 5.9; moderate aversion) and cockroaches on food ($M_{arousal}$ = 5.1; low aversion) (see Lenaert et al., 2014). There were two unpleasant noises. One was a 2 s, 80-db female scream, which was selected based on unpleasantness ratings of young adults (M = 1.21; high aversion) (Van Diest, Bradley, Guerra, Van den Bergh, & Lang, 2009). The other was a 0.2 s, 80 db of white noise, of low aversion (no normative information available). Images and noises were sorted into 4 levels. *Level-1* consisted of low aversive images and a low aversive noise. *Level-2* consisted of moderate aversive image and a low aversive noise. *Level-3* consisted of moderate aversive image and high aversive noise. *Level-4* consisted of the high aversive image and high aversive noise.

Sham-US unpleasantness ratings were recorded via paper and pencil on an 11-point Likert scale where 0 = neutral, 5 = mildly unpleasant and 10 = very unpleasant. US expectancy was measured using an 11-point Likert scale where 0 = definitely unlikely, 5 = uncertain and 10 = definitely likely. This scale appeared horizontally on the bottom of the screen and responses were made via a mouse click on the scale. Stimulus valence was measured using a 21-point Likert scale where -10 = highly unpleasant, 0 = neutral and +10 = highly pleasant. This scale appeared vertically on the side of the screen and responses were given via a mouse click.

2.3. Procedure

2.3.1. Sham-US Selection

Participants were instructed to select an unpleasant, but tolerable, combination of images and noises. The experimenter presented sham-USs from level 1 to level 4. After each presentation, the participants rated the unpleasantness of the sham-US and the next level was then presented. This continued until all 4 levels were completed or until participants selected a level that was most unpleasant. Once a level was selected participants were told that any future images and sounds would be from that level. However, the sham-US would not be presented again.

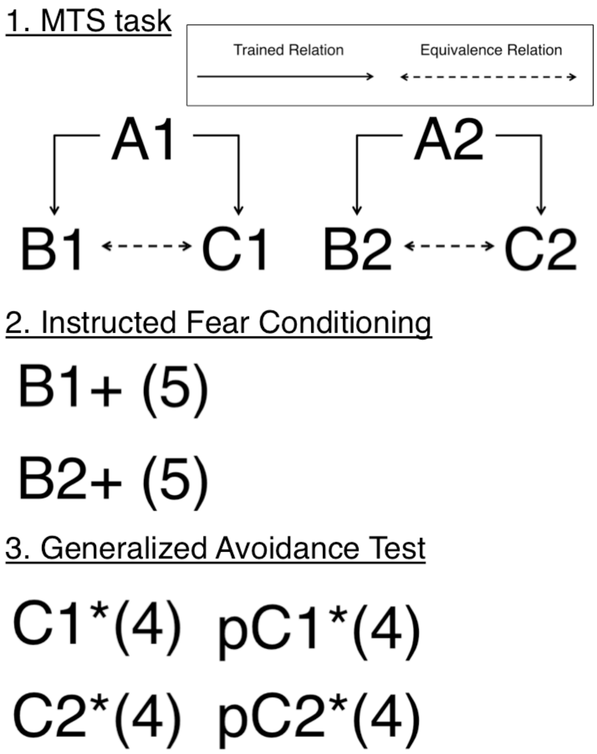

Figure 2. A schematic overview of the experimental procedure. The A1, B1 and C1 stimulus equivalence category is referred to as CAT+. The A2, B2 and C2 stimulus equivalence category is referred to as CAT-. The digit within the parentheses indicates the number of presentations of the stimulus. + indicates that the stimulus was paired with threatening information (i.e., a conditioned exciter). – indicates that the stimulus was paired with safety information (i.e., a conditioned inhibitor). * indicates that an avoidance response was available.

2.3.2. MTS Task

Initially, a picture of a quaver (150x150 pixels) appeared on the top of the screen. Clicking the quaver removed it and played a sample stimulus- [A1] or [A2]. This was followed 3 s later by the comparison stimuli- [B1, B2, B3] or [C1, C2, C3]. These stimuli appeared in a line on the bottom of the screen and order was randomized on all trials. Participants were instructed to select a comparison stimulus by pressing 1, 2 or 3 on a numeric keyboard where 1 = left stimulus, 2 = middle stimulus and 3 = right stimulus. There were 4 types of training trials- [A1]→ [*B1*, B2, B3], [A2]→ [B1, *B2*, B3], [A1]→ [*C1*, C2, C3] and [A2]→ [C1, *C2*, C3], with the correct choice in *italics* (see Figure 2). Making a selection removed all stimuli from the screen and presented corrective feedback. Correct selections were followed by the feedback "correct" for 3 s and incorrect selections were followed by the feedback "wrong" for 3 s. This was followed by a 3 s inter trial interval (ITI). Trials continued until 16 consecutively correct responses were made. Subsequent trials examined the interchangeability between comparisons stimuli, i.e. equivalence relations. Here, one comparison stimulus, e.g. [B1] appeared on the top of the screen for 5 s followed by the presentation of 3 other comparison stimuli at the bottom of the screen [i.e. C1, C2, C3]. There were 4 testing trial types- [B1]→ [*C1*, C2, C3], [B2]→ [C1, *C2*, C3], [C1]→ [*B1*, B2, B3] and [C2]→ [B1, *B2*, B3], with the correct selection in *italics*. Again, selections were made with a numeric keypad but no corrective feedback was given. Trials appeared quasi randomly 4 times each in a block of 16 trials.

2.3.3. Instructed Fear Conditioning

Participants were told that extra information would be given about the nonsense words. During these trials, a nonsense word stimulus (B1 or B2) appeared in the top-centre of the screen. This was followed 1 s later by the word "is" in the centre of the screen. Evaluative information then appeared 1 s later in the bottom-centre of the screen. B1 was paired with threatening information- *injury*, *terrible*, *danger*, *pain* and *hurt*. B2 was followed by safety information- *safe*, *secure*, *gentle*, *trust* and *peace*. B1 and B2 trials appeared 5 times each, quasi-randomly with no more than two consecutive presentations of the same type. Information remained on-screen for 4 s and was followed by a 5-9 s ITI. Therefore, the nonsense word from CAT+ was aversively instructed and the nonsense word from CAT- was appetitively instructed (see Figure 2).

2.3.4. Generalized Avoidance Test

Participants were informed that items would appear and that unpleasant images and sounds might follow. It was also stated that these could be avoided by pressing the space bar and a cue that read "space bar available" would indicate when this was possible. However, the sham-US was never presented. Four animal-like objects were presented; C1, C2, pC1 and pC2. This examined the generalization of avoidance to other members of CAT+ and CAT- (*category* *stimuli*; C1 & C2) and (ii) the perceptual generalization of avoidance to stimuli physically similar to the members of CAT+ and CAT- (*perceptual stimuli*; pC1 & pC2). Each object was presented 4 times each in a block of 16 trials. An object appeared centre-screen followed 1 s later by a cue "space bar available". If an avoidance response was made whilst a stimulus was on-screen the cue was removed. Overall, each stimulus remained on-screen for 5 s followed by a 3-9 s ITI (see Figure 2).

2.4. Outcome Measures

2.4.1. Behavioural Avoidance

During the generalized avoidance test, avoidance responses to C1 and C2 (category stimuli), and pC1 and pC2 (perceptually similar stimuli) were recorded. Participants had 4 opportunities to avoid each of these stimuli.

2.4.2. US Expectancy

Participants completed a series of questions after the generalized avoidance test. To ensure that the conditioning phase installed threat expectancy, US expectancy ratings were reported for the verbally conditioned stimuli from CAT+ and CAT- (i.e. B1 & B2). Also, US expectancy ratings were made in response to the category stimuli (i.e. C1 & C2) and perceptually similar stimuli (i.e. pC1 & pC2). US expectancy was first reported for stimuli when the avoidance response was assumed to be present. Stimuli were shown centre screen with the question- "Imagine that you *do press* the space bar. How likely was it that images and sounds would follow this? ". US expectancy was then reported when the avoidance response was assumed to be absent. The question now read, "Imagine that you *do not* press the space bar. How likely was it that images and sounds would follow this? ".

2.4.3. Stimulus Valence Ratings

In order to ensure that conditioning phase changed the evaluative nature of stimuli, valence ratings were also reported for the conditioned stimuli (i.e. B1 & B2). In addition, stimulus valence ratings were recorded for the category stimuli (i.e. C1 & C2) and the perceptual stimuli (i.e. pC1 & pC2). This took place before the conditioning phase and again after generalized avoidance test.

2.5. Data Analysis

The mean unpleasantness for each sham-US level was calculated. The number of MTS training trials for each participant was calculated and the accuracy was calculated by expressing the total number of correct trials as a percentage of the overall number of training trials. The number of correct equivalence testing trials in the MTS task was also calculated for each participant and an accuracy score was calculated by expressing this as a percentage of the overall number of testing trials. An accuracy of 87.50% during the equivalence test (14/16 correct trials) was assumed to indicate the establishment of stimulus equivalence categories. All participants met this requirement. The percentage of generalized avoidance responses emitted in the presence of stimuli for each stimulus was calculated for each participant. A repeated measure ANOVA was conducted to assess the effect of stimulus (B1, B2, C1, C2, pC1, & pC2) on avoidance. The mean retrospective US expectancy for each stimulus (B1, B2, C1, C2, pC1, & pC2) was also calculated while (i) the avoidance response was assumed to be absent and (ii) the avoidance response was assumed to be present. Two repeated measures ANOVA were conducted to assess the effect of stimulus on these US expectancy ratings.

Self-reported stimulus valence ratings were reported for each stimulus (B1, B2, C1, C2, pC1 & pC2) pre-instructed fear conditioning (X) and post-generalized avoidance test (Y). A mean difference score was then calculated (d = Y - X) for each stimulus to measure evaluative changes. A negative mean d-score indicates that valence ratings for a stimulus became negative while a positive mean d-score indicated that ratings became positive. A repeated measure ANOVA was calculated to assess the effect of stimuli on valence change.

Where Mauchly's test revealed that sphericity could not be assumed the Greenhouse-Geisser correction is reported. Effect size was calculated using the partial ETA squared (η_P^2). The alpha-level was set at .05 and Bonferroni corrections were used as the rejection criterion when pairwise comparisons were calculated.

3. Results

3.1. Sham-US Selection

The sham-US from level-1 was the least aversive ($M_{unpleasantness} = 1.63$, $SE = 0.29$; 3.30% of participants). The next lowest was level-2 ($M_{unpleasantness} = 2.74$, $SE = 0.33$; 16.70% of participants) and then level-3 ($M_{unpleasantness} = 4.04$, $SE = 0.33$; 36.70% of participants). Finally, level 4 was the most aversive option ($M_{unpleasantness} = 6.31$, $SE = 0.38$; 43.00% of participants).

3.2. Matching-to-Sample Task

A mean of 66.13 MTS training trials ($SE = 14.89$) were completed and there was a high accuracy of responding ($M_{accuracy} = 86.85\%$, $SE = 1.39\%$). All participants passed the subsequent testing phase with a mean of 15.9 correct responses ($SE = 0.06$) and a high accuracy of responding ($M_{accuracy} = 98.43\%$, SE = 0.35). This suggests that two stimulus equivalence categories (CAT+ & CAT-) were reliably established.

3.3. Generalized Avoidance

There was a main effect of stimulus on generalized avoidance, F (38, 61) = 38.26, p = .01, $\eta_P^2 = 0.57$ (see Figure 3a). Planned comparisons revealed a significant difference in category stimuli-, $t = 9.85$, $p < .001$, $df = 29$. Therefore, avoidance specifically generalized to animal-like objects within the aversive equivalence category (CAT+) and not the appetitive category (CAT-). In addition, there was a significant difference between the perceptually similar stimuli, t = 4.63, $p < .001$, $df = 29$. Avoidance also generalized to animal like-objects that were perceptually similar to members of the CAT+ and not CAT-. However, C1prompted more avoidance than pC1, $t = 3.31$, $p = .003$, $df = 29$, indicating more generalization to the category stimulus than its perceptual variant.

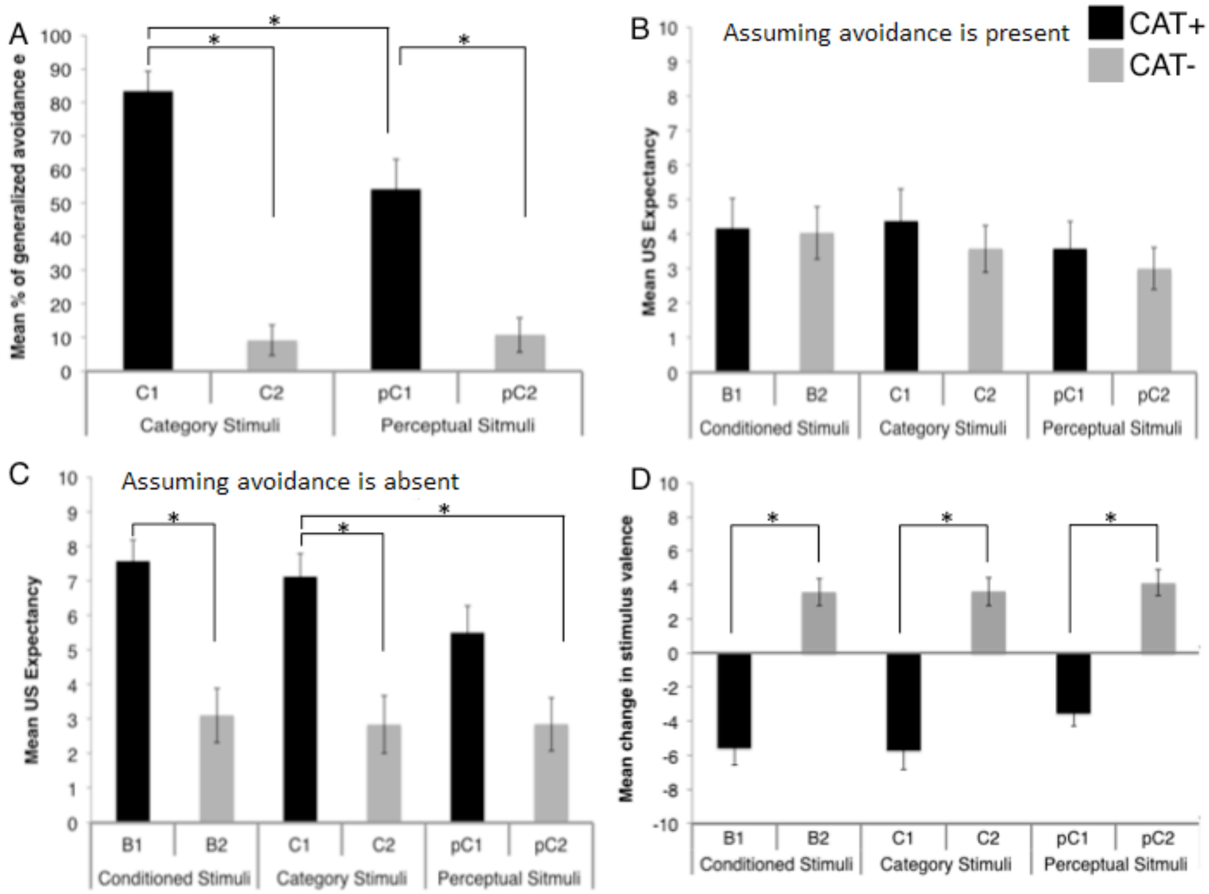

Figure 3. (A) Mean number of avoidance responses. (B) Mean US expectancy ratings when the avoidance response was assumed to be present. (C) Mean US expectancy ratings when the avoidance response was assumed to be absent. (D) Mean valence change for stimuli. Error bars represent standard error.

3.4. Retrospective US Expectancy

US expectancy was reported retrospectively while assuming that an avoidance response was present. There was no main effect of stimulus on these ratings, $F\ (3, 61) < 1, p = .41$ (see Figure 3b). The mean rating for each stimulus was low suggesting that participants associated avoidance with an absent US.

US expectancy was also reported assuming that an avoidance response was absent. A main effect of stimulus was observed, $F\ (2, 42) = 9.19, p < .01, \eta_P^2 = 0.27$ (see Figure 3c).

Planned comparisons revealed that the conditioned stimuli significantly differed, $t = 3.34$, $p = .002$, $df = 25$. Information successfully apparently conditioned B1 to predict an aversive outcome and B2 to predict a non-aversive outcome. Planned comparisons also indicated that the US expectancy ratings for category stimuli significantly differed, $t = 3.31$, $p = .003$, $df = 25$. Therefore, US expectancy generalized to animal-like objects within the aversive equivalence category (CAT+) and not the appetitive equivalence category (CAT-). Mean US expectancy for stimuli perceptually similar to the members of CAT+ and CAT- did not differ (using Bonferroni's correction), $t = 2.53$, $p = .01$, $df = 25$. However, the category member of CAT+ (C1) did not significantly differ from its perceptually similar stimulus (pC1), $t = 1.84$, $p = .07$, $df = 25$, but did differ from the other perceptual stimulus (pC2), t = 3.44, $p = .002$. This suggests that there was some generalization of US expectancy to animal-like objects perceptually similar to members of the aversive equivalence category.

3.4. Stimulus Valence

There was a main effect of stimulus on valence change, F (2, 49) = 29.11, $p < .01$, $\eta_p^2 = 0.52$ (see Figure 3d). Planned comparisons indicated that conditioned stimuli significantly differed, $t = -6.39$, $p < .001$, $df = 27$, suggesting that instructions successfully conditioned B1 as aversive and B2 as appetitive. Planned comparisons also indicated a significant difference in the valence scores of the category stimuli, $t = -5.46$, $p < .001$, $df = 27$. Therefore, negative evaluations generalized to animal-like objects from the aversive equivalence category (CAT+) while positive evaluations generalized to animal-like objects from the appetitive equivalence category (CAT-). Planned comparisons also revealed a significant difference between perceptual similar stimuli, t = -5.49, $p < .001$, $df = 27$. This suggests that (i) negative evaluations generalized to animal-like objects perceptually similar to those from the aversive equivalence category (pC1) and (ii) positive evaluations generalized to animal-like objects perceptually similar to those from the appetitive equivalence category (pC2).

4. Discussion

The present study demonstrates that conceptual and perceptual similarity can simultaneously facilitate the spreading of instructed fear. First, the results clearly show that fear generalized from aversively conditioned nonsense words to animal-like objects within the same stimulus equivalence category. This finding is especially interesting when considering that these objects (i) were never explicitly related to the nonsense words, (ii) were perceptually dissimilar from the nonsense words and (iii) were never directly or indirectly paired with a US (Auguston & Dougher, 1997; Dymond et al., 2011; Vervoort et al., 2014; Valverde et al., 2009). Second, physically similar animal-like objects, which were not explicitly category members, also evoked heightened fear. The scope of fear generalization essentially increased as the perceptual features of one object overlapped with another that was conceptually connected to a threat relevant word. These findings show how learned fear might spread to a variety of arbitrary events that never featured in an aversive episode. In the case of a phobia, for example, a person might develop a fear of blood-injections which might generalize to categorically related events (e.g. nurses with white coats) as well as to their perceptual variants (e.g. science teachers with white coat; e.g. Dunsmoor et al., 2012).

The current study attempted to model real-life fear learning and generalization in two ways. First and most notably, the potential for both the perceptual and conceptual relations between stimuli to interact and exacerbate fear generalization was demonstrated. Presently, perceptual generalization research scarcely speaks to the role of conceptual meaning while conceptual generalization research rarely addresses the importance of physical form. While examining these mechanisms separately can afford an unambiguous focus for individual studies, it may be at the cost of external validity. Real-world events are laden with both perceptual and conceptual information and not just one or the other. Second, we employed an instructed fear conditioning paradigm where nonsense words were paired with threatening information.

Typically in fear research, stimuli are directly paired with an intense US but origin of anxiety can often be traced to verbal exchanges (Rachman, 1977). We have mimicked this important pathway for fear acquisition and, also, furthered the scope of inquiry by demonstrating that instructed fear can generalize to perceptually and conceptually related events. Overall, investigating the both conceptual and perceptual generalization of instructed fear is an important step towards better understanding the expansion of fear in anxiety disorders. Indeed, our experimental model bears a surprising resemblance to the experiences of a patient with OCD who struggled with fears of contamination and an ever-increasing network of triggers (described by McGinn & Sanderson, 1999). On one occasion, for instance, the patient was verbally informed that her sister-in-law was ill with a bout of diarrhea. This information altered the patient's emotional responding to her actual sister-in-law who now elicited disgust and triggered compulsive behaviors- an instance of conceptual generalization. Moreover, this maladaptive fear spread to the extent that even photographs of her sister-in-law triggered her OCD symptoms causing her to remove them from the home- an instance of perceptual generalization.

Participants grouped stimuli into meaningful categories, which facilitated the generalization of instructed fear. That is, nonsense words and animal-like objects were functionally interchangeable such that an aversive experience with one altered emotional responding to the other. The question remains as to why the perceptually similar objects evoked fear. One explanation is that the physically similar objects also became category members. Fields and colleagues (1991) indeed demonstrated that physical variants of category members become interchangeable with other category members. In that study, a MTS task established a stimulus equivalence category where nonsense word stimuli and dashed-lines were equivalent. In subsequent MTS trials, dashed-lines were replaced with physical variants and these were more likely to be related to the nonsense words when they resembled the original lines. In the present study, animal-like objects that resembled members from the stimulus equivalence category could have also become part of the artificial category and, therefore, related to the conditioned stimulus. In this case, category membership generalized perceptually to variants of members of the category and fear then generalized to these new members. Alternatively, of course, the common elements shared between the actual members of the stimulus equivalence category and the perceptually variants could have facilitated the generalization of fear.

It is interesting to note that avoidance generalized more to category stimuli than to the perceptual variants, despite the fact that both were physically unlike the conditioned stimulus. A similar trend was also observed for the US-expectancy ratings and valence ratings but did not reach statistical significance. Still, this outcome suggests that a close category relationship between stimuli has a marked impact on generalized avoidance. That is, the category stimulus participated in the MTS training, which rendered it a more typical category member than the perceptual stimulus. This is consistent with recent research showing that the degree of conceptual similarity between two stimuli facilitates the generalization of learned fear (e.g. Dunsmoor, White, & LaBar, 2011; Dunsmoor & Murphy, 2014). Generally speaking, the current study adds to a growing body of literature indicating how the representation of an entire category can become involved in a conditioning episode (Dunsmoor & Murphy, in press). Moreover, category relationships can be rather arbitrary and generalization can, as a consequence, be unrestricted by physical form. This creates the possibility for a broad network of events to become emotionally significant; perhaps more than could be achieved by perceptual generalization alone (e.g. Bennett, Hermans, Dymond, Vervoort & Baeyens, 2014).

Our findings are consistent with previous research by Barnes and Kennan (1993) that investigated how both conceptual and perceptual relations interact in the generalization of basic operant responses. Two stimulus equivalence categories were shaped using a MTS task with nonsense word stimuli. Specific key press patterns were then shaped. A member from one category controlled a low rate of responding and a member from the other category controlled a high rate of responding. In a final testing phase, response rates specifically generalize to members of the same category and previously unseen stimuli that physically resembled these other members. The present study has extended on this earlier research in the context fear.

An expectancy-based account of avoidance asserts that avoidance is mediated by beliefs about potential threat and about the reliability of the avoidance in averting threat (Lovibond, 2006). It is therefore unusual that category and perceptual stimuli elicited equal US expectancy ratings but different levels of avoidance. This could suggest that expectancy does not underlie perceptually and conceptually generalized avoidance to the same extent. Alternatively, this could point to a procedural limitation as US expectancy was retrospectively rated and relied on memory. As such, these reports may not have been sensitive to subtle differences between these stimuli when they were first encountered. Future research should examine if the dissociation between US expectancy and avoidance is erased when more reliable trial-by-trail ratings are employed (Lovibond, 2006). In addition, our measures were mostly self-reported and, as such, may have been sensitive to desirability effects. It could therefore be interesting for future studies to employ direct physiological measures of fear including skin conductance and fear-startle potentials that are less likely to be subject to voluntary control (e.g. Lissek et al., 2008; Vervoort et al., 2013).

This study speaks solely to the expansion of fear and it will be important for future research to investigate the therapeutic implications of both generalization processes. A goal of exposure therapy, for instance, is that extinction learning generalizes to a network of fear-relevant stimuli. But the evidence suggests that the generalization of extinction is limited when a perceptual or conceptual variant of the originally conditioned stimulus is extinguished (see Vervliet, Kindt, Vansteenwegen, & Hermans, 2005; Vervoort et al., 2014). Our position, however, could imply that extinction research should capitalize on both the perceptual and conceptual relations that stimuli have with conditioned stimuli. Perhaps extinction learning would readily generalize if the extinguished stimuli were both similar to the originally conditioned stimulus as well as highly typical category exemplar.

In conclusion, the present study highlights how complex conceptual and perceptual relations between stimuli might exacerbate the spreading of instructed fear. Under the assumption that (over)-generalization is a characteristic symptom of anxiety disorders, these findings may be important in understanding how a nexus of innocuous events can evoke fear following a threatening episode.

5. References

Augustson, E. M., & Dougher, M. J. (1997). The transfer of avoidance evoking functions through stimulus equivalence classes. *Journal of Behavior Therapy and Experimental Psychiatry*, *28*, 181–91.

Barnes, D., & Keenan, M. (1993). Concurrent activities and instructed human fixed-interval performance. *Journal of the Experimental Analysis of Behavior, 59*, 501-520.

Barry, T. J., Griffith, J. W., De Rossi, S., & Hermans, D. (2014). Meet the Fribbles: novel stimuli for use within behavioural research. *Frontiers in Psychology*, *5*, 103.

Bennett, M., Hermans, D., Dymond., Vervoort, E., & Baeyens, F. (in press). From bad to worse: Symbolic equivalence and opposition in fear generalization. *Cognition and Emotion*.

Coelho, C. M., & Purkis, H. (2009). The origins of specific phobias: Influential theories and current perspectives. *Review of General Psychology*, *13*, 335–348.

Dunsmoor, J., Martin, A., & LaBar, K.S. (2012). Role of conceptual knowledge in learning and retention of conditioned fear. *Biological Psychology, 89*, 300-305.

Dunsmoor, J. E., & Murphy, G. L. (2014). Stimulus Typicality Determines How Broadly Fear Is Generalized. *Psychological Science*, 1–6.

Dunsmoor & Murphy (In Press) Categories, Concept, & Conditioning: how humans generalize fear. TiCS

Dymond, S., Schlund, M. W., Roche, B., De Houwer, J., & Freegard, G. P. (2012). Safe from harm: Learned, instructed, and symbolic generalization pathways of human threat-avoidance. *PloS one*, *7*(10), e47539.

Dymond, S., Dunsmoor, J. E., Vervliet, B., Roche, B., & Hermans, D. (2014). Fear generalization in humans: Systematic review and implications for anxiety disorder research. *Behavior Therapy*.

Dymond, S., Schlund, M. W., Roche, B., Whelan, R., Richards, J., & Davies, C. (2011). Inferred threat and safety: symbolic generalization of human avoidance learning. *Behaviour Research and Therapy*, *49*, 614–21.

Fields, L., Reeve, K.F., Adams, B.J., Verhave, T. (1991). Stimulus generalization and equivalence classes: A model for natural categories. *Journal of the Experimental Analysis of Behavior, 55,* 305-312.

Galizio, M., & Stewart, K. L. (2001). Clustering in artificial categories: An equivalence analysis. *Psychonomic Bulletin & Review*, *8*(3), 609-614.

Grühn, D., & Scheibe, S. (2008). Age-related differences in valence and arousal ratings of pictures from the International Affective Picture System (IAPS): Do ratings become more extreme with age? *Behavior Research Methods*, *40*, 512–521.

Haddad, A. D., Xu, M., Raeder, S., & Lau, J. Y. (2013). Measuring the role of conditioning and stimulus generalisation in common fears and worries. *Cognition & emotion*, *27*, 914-922.

Hayes, S. C., Barnes-Holmes, D., & Roche, B. (Eds.). (2001). Relational frame theory: A post-Skinnerian account of human language and cognition. New York: Plenum Press.

Hermans, D., Baeyens, F., & Vervliet, B. (2013). Generalization of acquired emotional responses. In M. D. Robinson, E. R.Watkins, & E. Harmon-Jones (Eds.), *Handbook of cognition and emotion* (pp. 117-134). New York: Guilford Press.

Kalish, H. I. (1969). Stimulus generalization. *Learning: processes*, 207-297.

Lang, P., Bradley, M., & Cuthbert, B. (2001). *International affective picture system (IAPS). Instruction manual and affective rating*. *Technical Report A-5*. Centre for Research in Psychophysiology: University of Florida.

Lenaert, B., Boddez, Y., Griffith, J. W., Vervliet, B., Schruers, K., & Hermans, D. (2014). Aversive learning and generalization predict subclinical levels of anxiety: A six-month longitudinal study. *Journal of Anxiety Disorders, 28,* 747-753.

Lissek, S., Biggs, A. L., Rabin, S. J., Cornwell, B. R., Alvarez, R. P., Pine, D. S., & Grillon, C. (2008). Generalization of conditioned fear-potentiated startle in humans: experimental validation and clinical relevance. *Behaviour Research and Therapy*, *46*(5), 678–87.

Lissek, S., Powers, A. S., McClure, E. B., Phelps, E. A, Woldehawariat, G., Grillon, C., & Pine, D. S. (2005). Classical fear conditioning in the anxiety disorders: a meta-analysis. *Behaviour Research and Therapy*, *43*, 1391–424.

Lissek, S., Rabin, S.J., Heller, R.E., Luckenbaugh, D., Geraci, M., Pine, D.S., & Grillon, C. (2010). Overgeneralization of conditioned fear as a pathogenic marker of panic disorder. *American Journal of Psychiatry*, 167, 47-55.

Lommen, M. J. J., Engelhard, I. M., & van den Hout, M. a. (2010). Neuroticism and avoidance of ambiguous stimuli: Better safe than sorry? *Personality and Individual Differences*, *49*, 1001–1006.

Lovibond, P. (2006). Fear and avoidance: An integrated expectancy model. In M. Craske, D. Hermans, & D. Vansteenwegen, *Fear and learning: Basic science to clinical application* (pp. 117-132). Washington DC: American Psychiatric Association.

McLaren, I. P. L., & Mackintosh, N. J. (2002). Associative learning and elemental representation: II. Generalization and discrimination. *Animal Learning & Behavior*, *30*, 177-200.

McGinn, L., & Sanderson, W.C. (1999). Treatment of obsessive compulsive disorder: Clinical application of evidence-based psychotherapy. Rowman & Littlefield, UK.

Muris, P., & Field, A. P. (2010). The role of verbal threat information in the development of childhood fear. “Beware the Jabberwock!”. *Clinical Child and Family Psychology Review*, *13*, 129–50.

Ollendick, T. H., & King, N. J. (1991). Origins of childhood fears: An evaluation of Rachman's theory of fear acquisition. *Behaviour Research and Therapy*, *29*, 117-123.

Olsson, A., & Phelps, E. A. (2004). Learned fear of “unseen” faces after Pavlovian, observational, and instructed fear. *Psychological Science*, *15*(12), 822-828.

Rachman, S. (1977). The conditioning theory of fear-acquisition: a critical examination. *Behaviour Research and Therapy*, *15*(5), 375–87.

Raes,A.K., De Houwer, J., De Schryver, M., Brass, M., Kalisch, R. (2014) Do CS-US Pairings Actually Matter? A Within-Subject Comparison of Instructed Fear Conditioning with and without Actual CS-US Pairings. PLoS ONE 9(1): e84888.

Spruyt, A., Clarysse, J., Vansteenwegen, D., Baeyens, F., & Hermans, D. (2010). Affect 4.0: A free software package for implementing psychological and psychophysiological experiments. *Experimental Psychology, 57*, 36-45.

Storms, G. (2003). Concept representation and the structure of semantic memory. In P. P. De Deyn, E. Thiery, & R. D'Hooge (eds.), *Memory: Basic concepts, disorders, and treatment* . Acco, Leuven.

Van Diest, I., Bradley, M.M., Guerra, P., Van den Bergh, O., & Lang., P.J. (2009). Fear-conditioned respiration and its association to cardiac activity. *Biological Psychology, 80*, 212-217.

Vervliet, B., Kindt, M., Vansteenwegen, D., & Hermans, D. (2010). Fear generalization in humans: impact of verbal instructions. *Behaviour Research and Therapy*, *48*, 38–43.

Vervoort, E., Vervliet, B., Bennett, M., & Baeyens, F. (2014). Generalization of human fear acquisition and extinction within a novel arbitrary stimulus category. *PloS One*, *9*, e96569.